

Strong Ground Motion Simulation of the 2023 Mw7.8 Türkiye Earthquake Using EQSIM

Arben Pitarka
Lawrence Livermore
National Laboratory

Kazuo Somei
Ken Miyakoshi
Ohsaki Research Inst.
Tokyo, Japan

Aybige Akinchi
Pietro Artale Harris
INGV, Rome, Italy

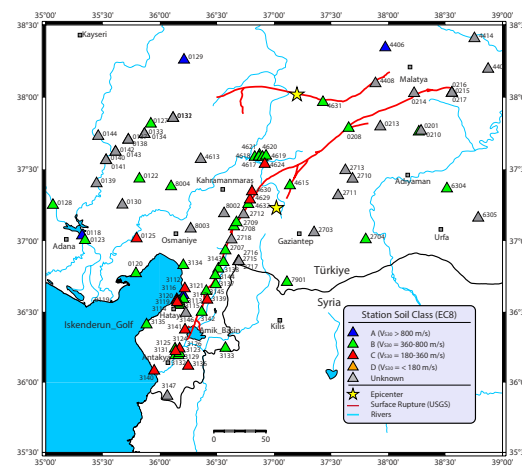
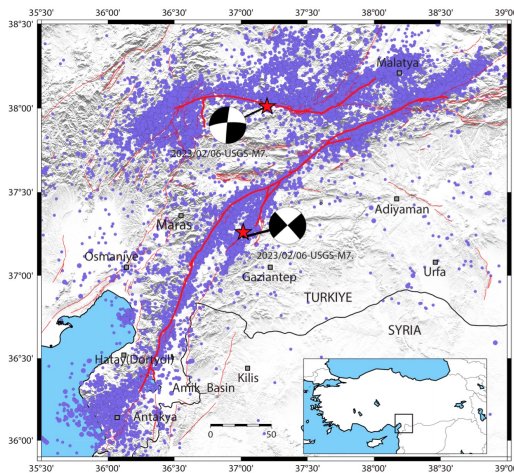
Dave McCallen
Lawrence Berkeley
National Laboratory

PEER-LBL Workshop May 7-8, 2026



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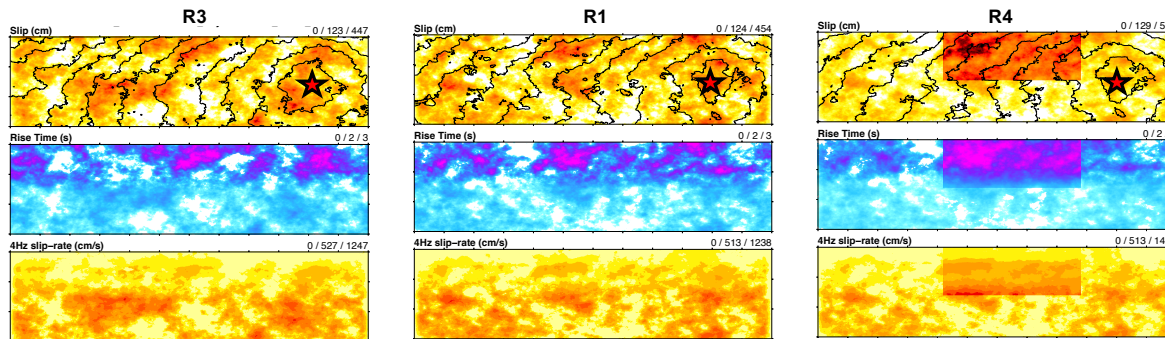
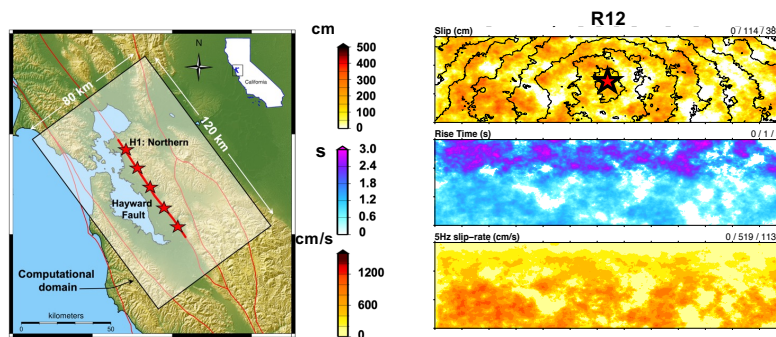
1. Test the performance of EQSIM and GP rupture model in BB (0-5Hz) simulations of Türkiye earthquake
2. Application to investigate the sensitivity of near-fault ground motion amplitude and amplification pattern to rupture speed



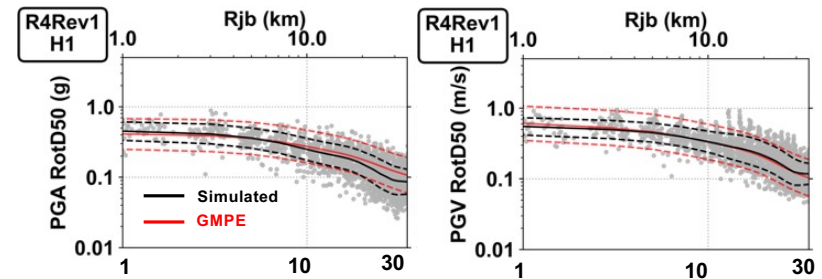
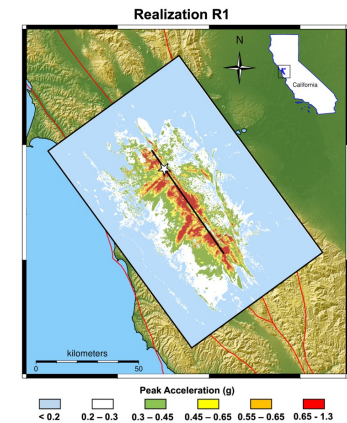
Rupture models used in creating the PEER-LBL synthetic database include fully-stochastic and hybrid slip models

McCallen et al., 2026

GP Kinematic Rupture Generator

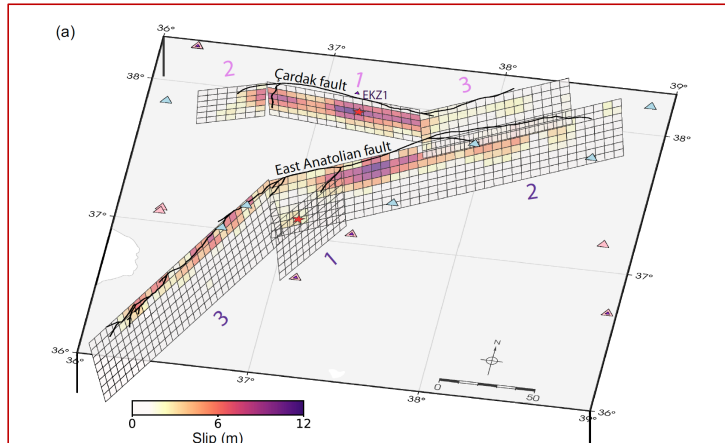


Validation against GMMs

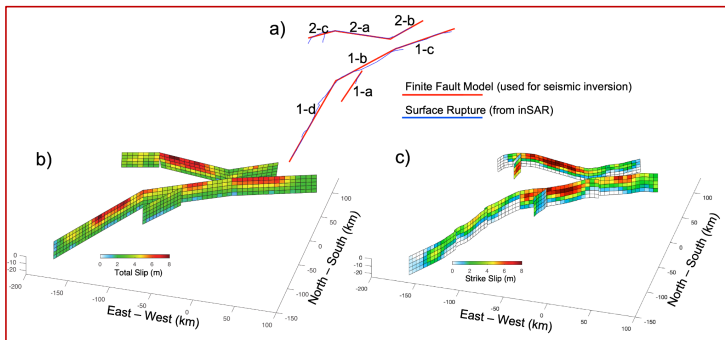


EQSIM performance in ground motion simulations of M7.8 2023 Türkiye Earthquake

Goldberg et al. (Seismic Record, 2025)



Mai et al. (Seismic Record, 2025)

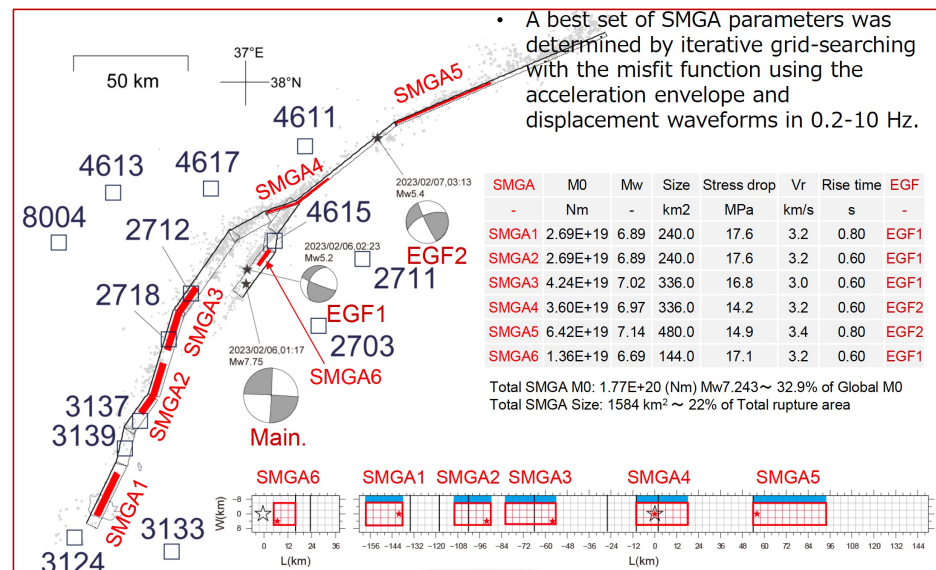


Observations:

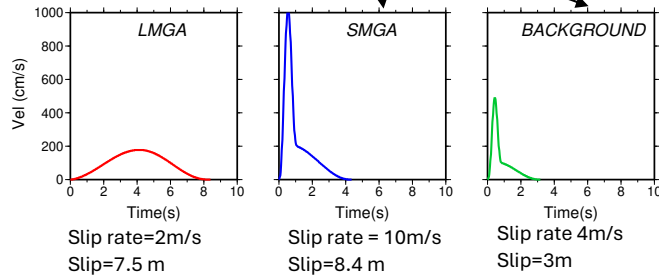
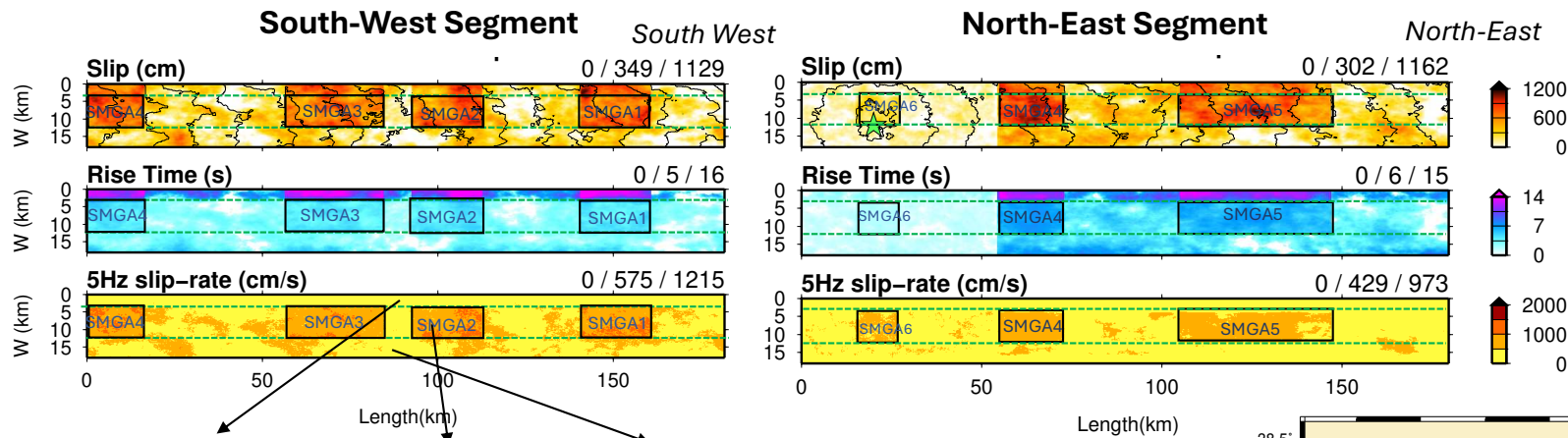
1- extended areas of shallow slip

2-supershear rupture velocity in parts of the fault

Somei al. (2026) model used in this study

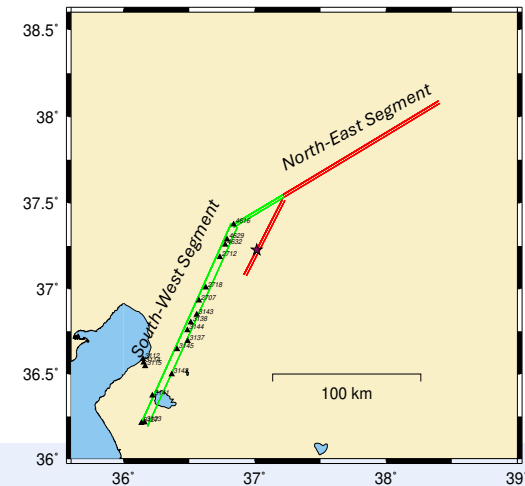


GP rupture model of 2023 Türkiye earthquake



Average Rupture Speed:
 $V_r = 0.90 V_s$

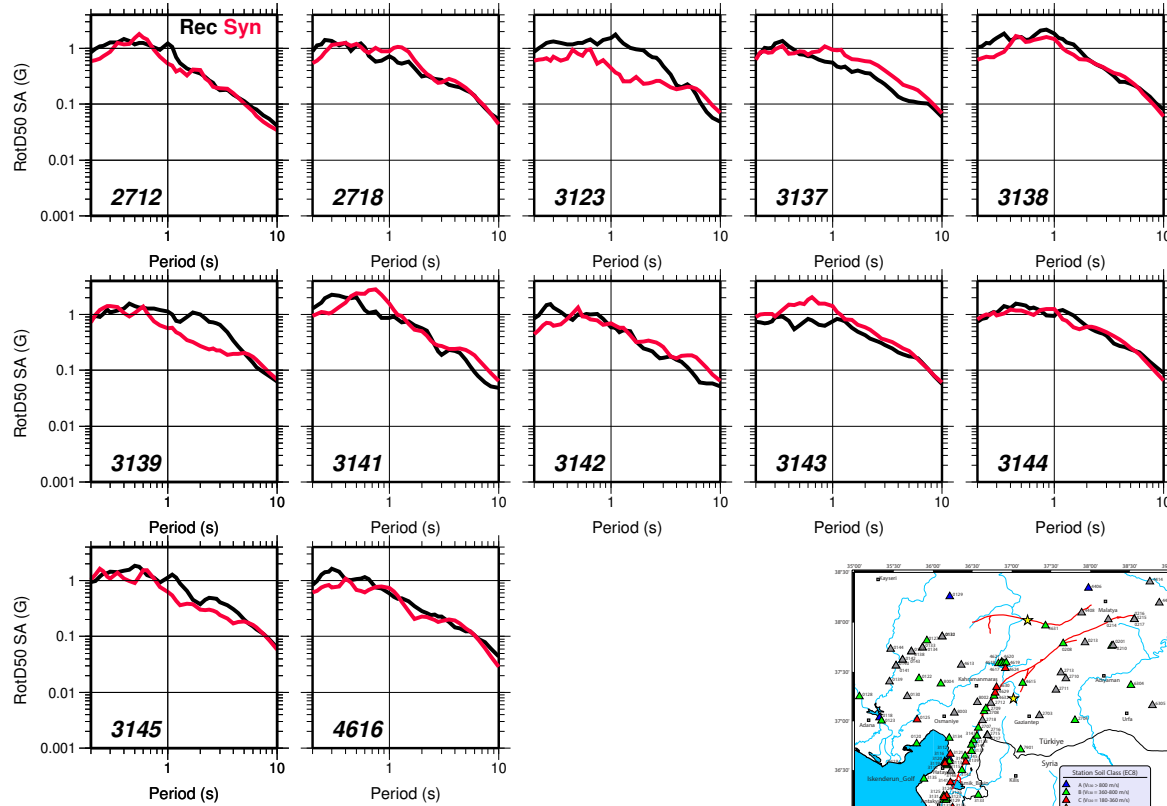
Slip rate functions
 (Pitarka et al., BSSA 2022)



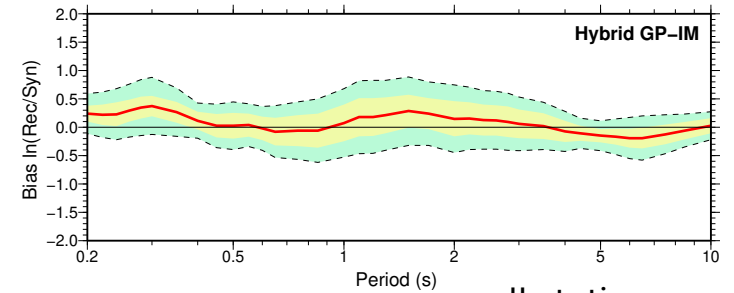
Goodness-of-fit for RotD50 SA



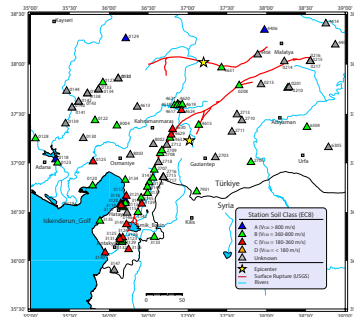
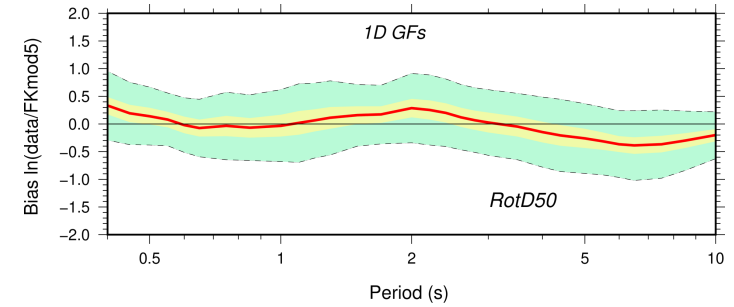
12 near-fault stations



12 stations

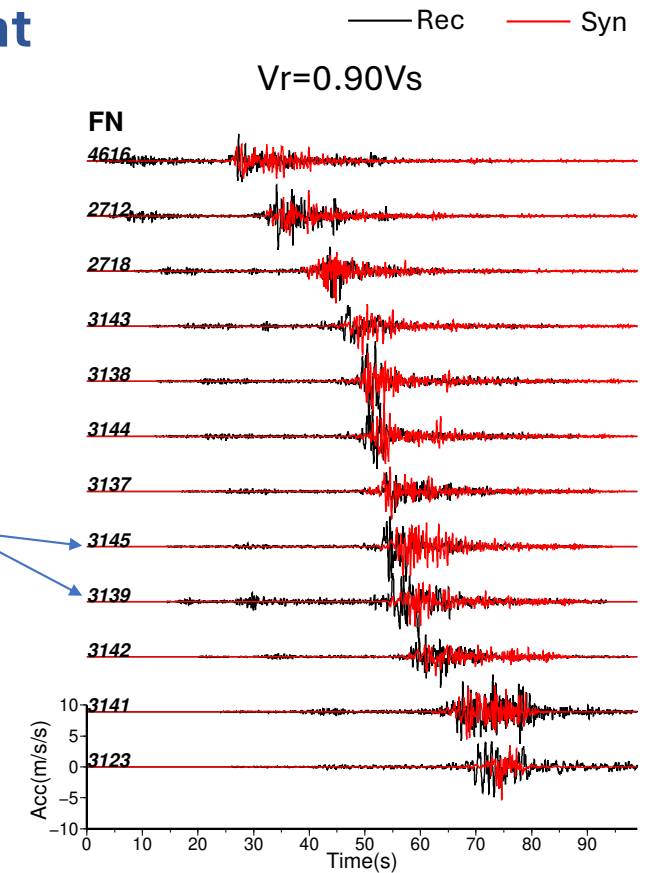
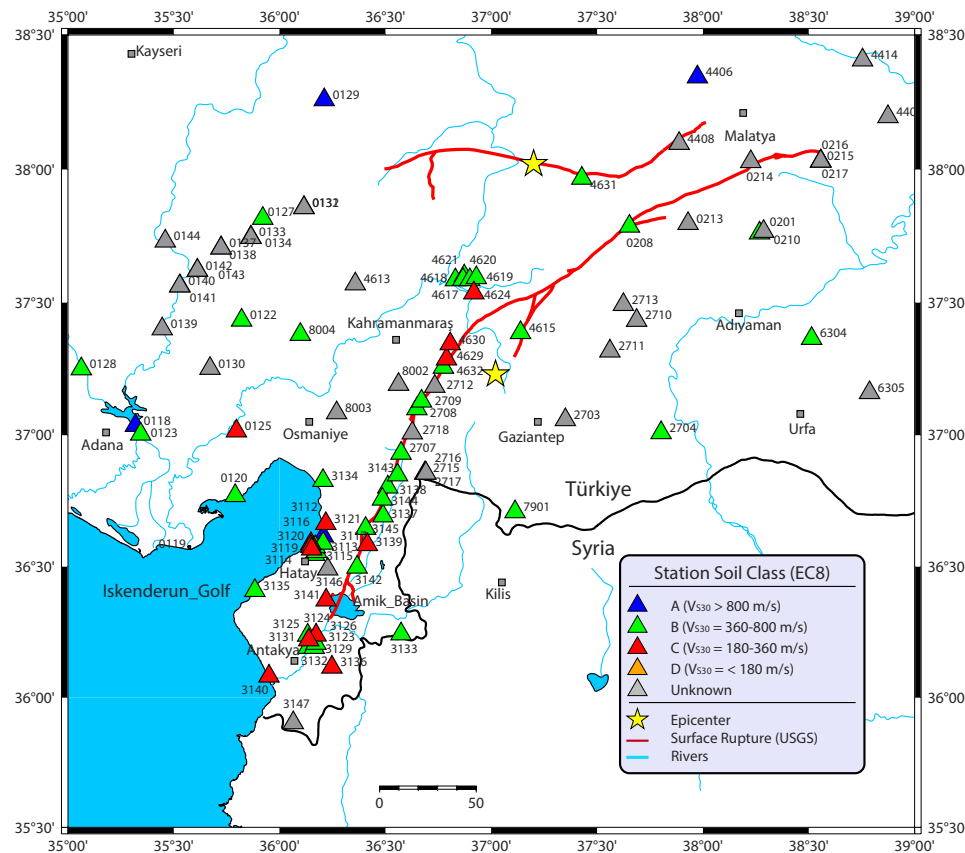


all stations



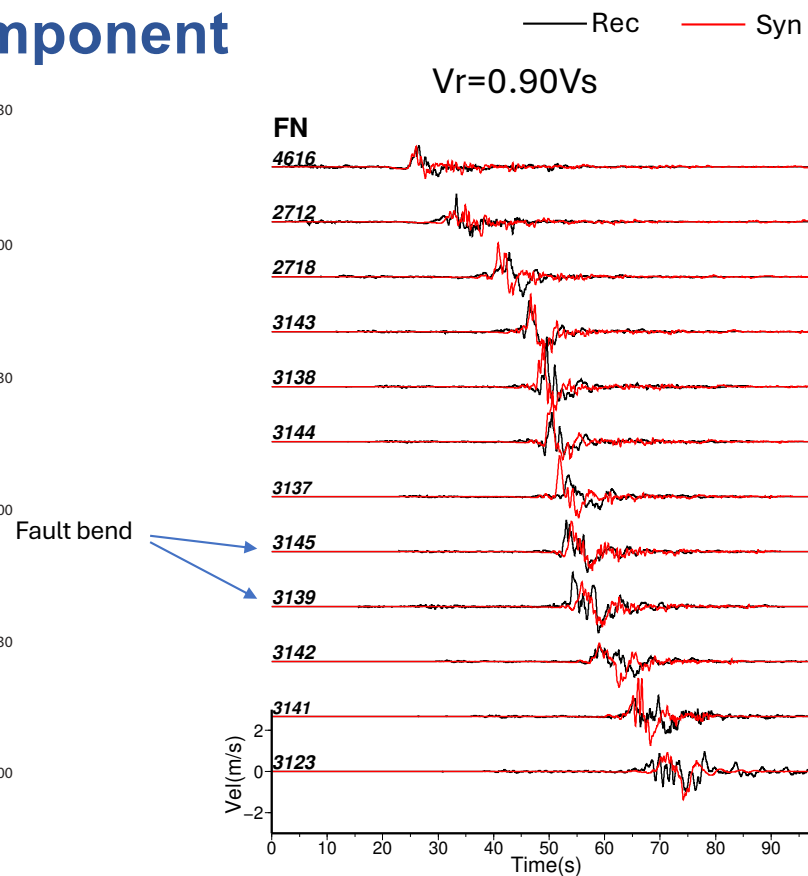
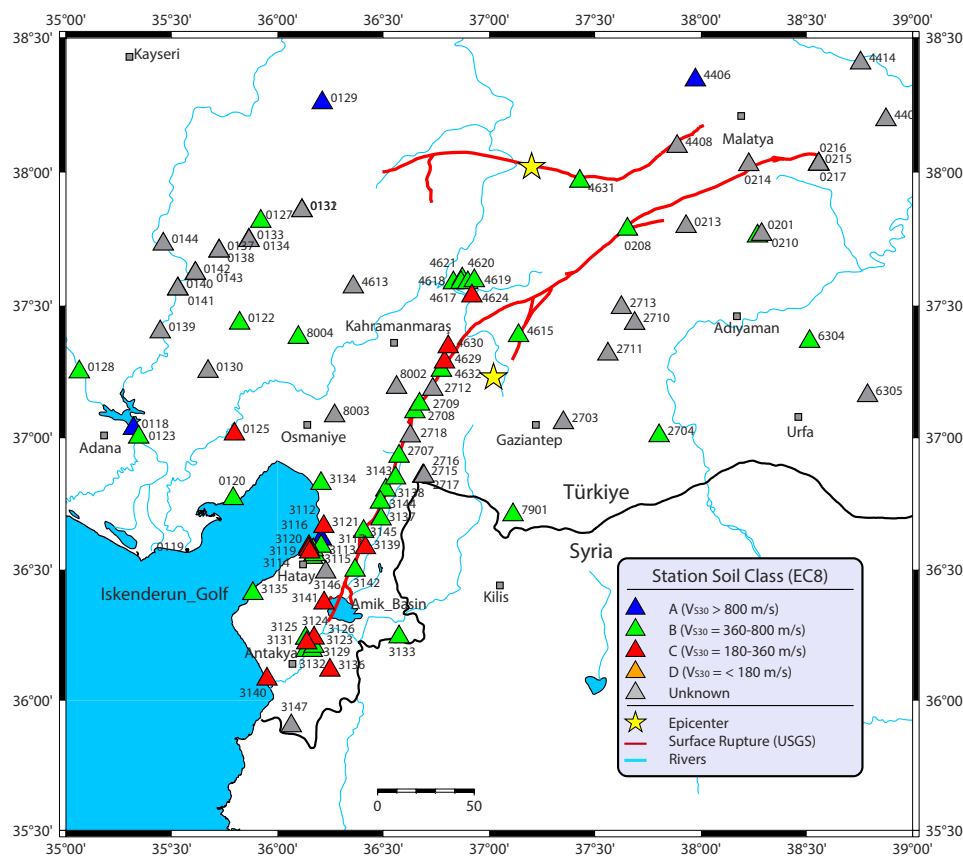
Comparison of recorded and simulated ground motion

Acceleration FN- Component



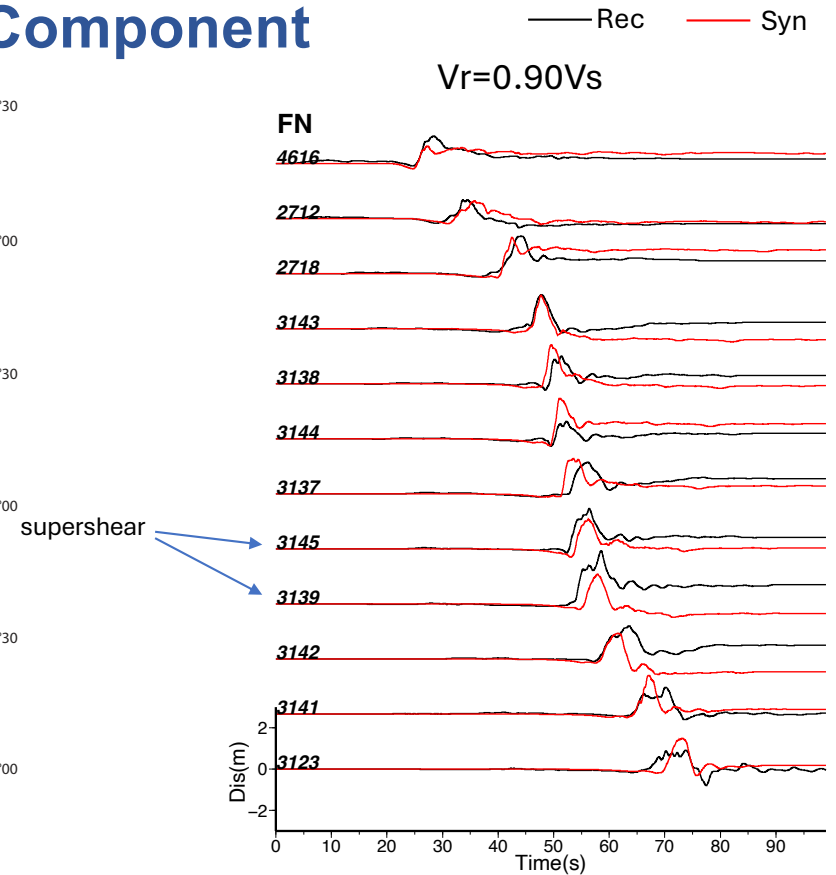
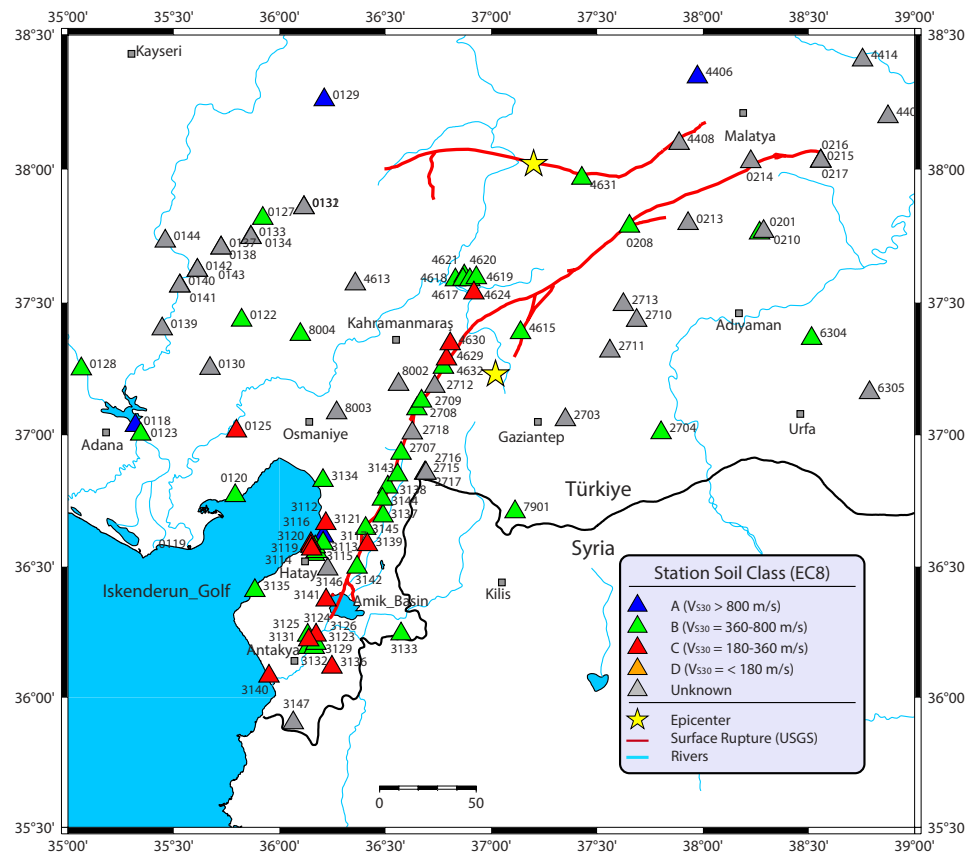
Comparison of recorded and simulated ground motion

Velocity FN- Component



Comparison of recorded and simulated ground motion

Displacement FN- Component



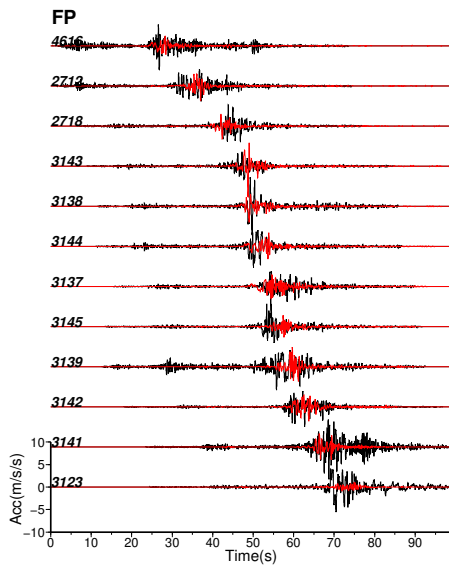
Comparison of recorded and simulated ground motion



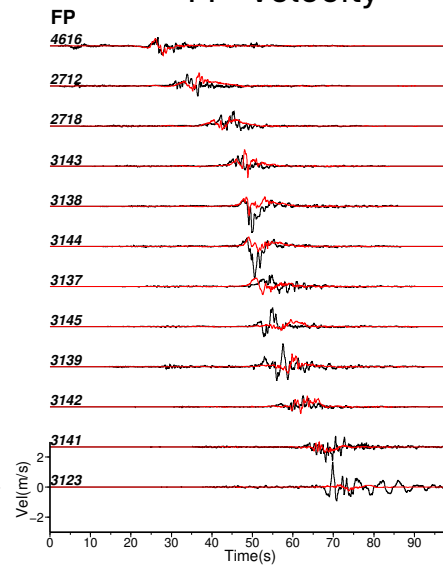
FP- Component

— Rec — Syn

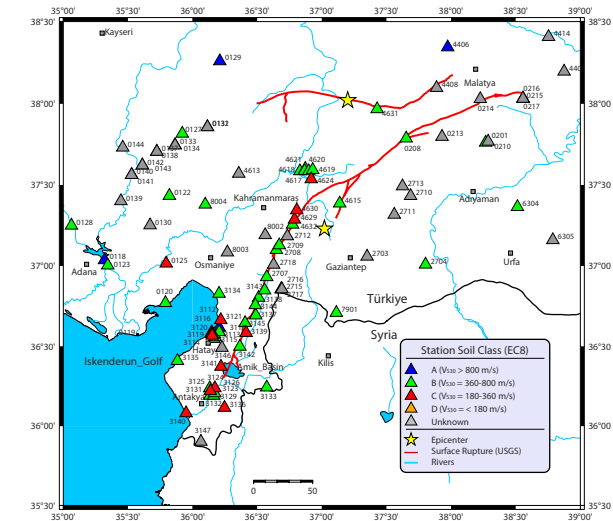
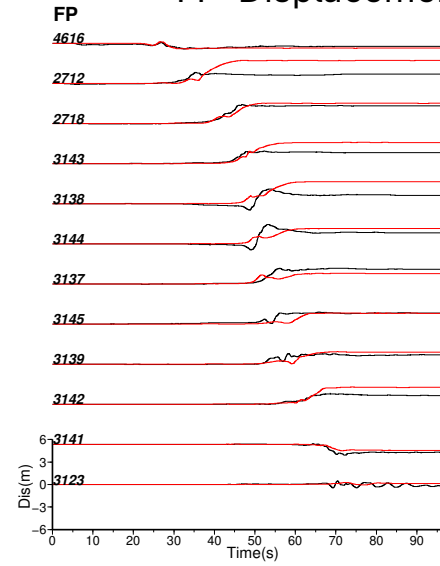
FP- Acceleration



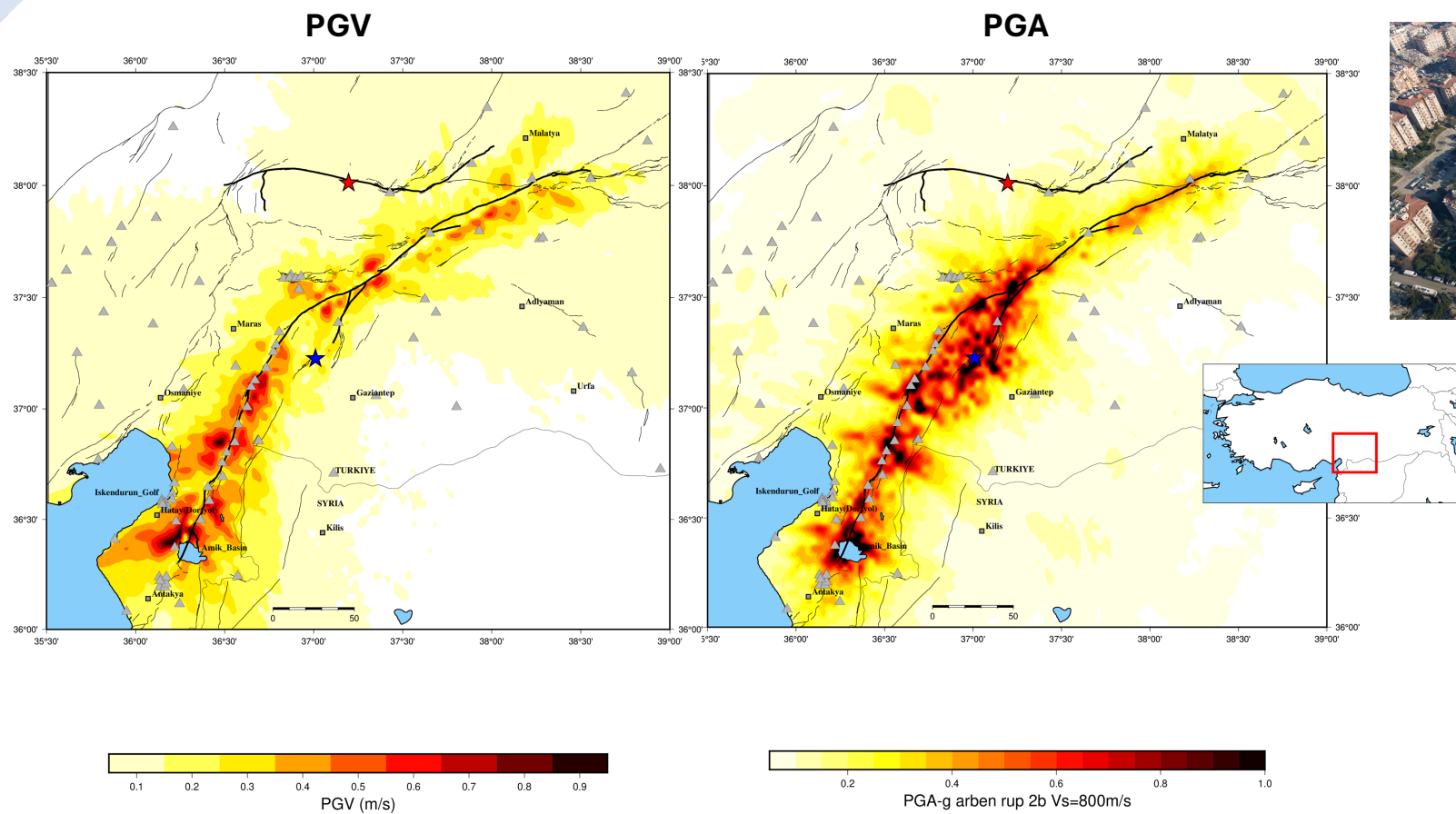
FP- Velocity



FP- Displacement



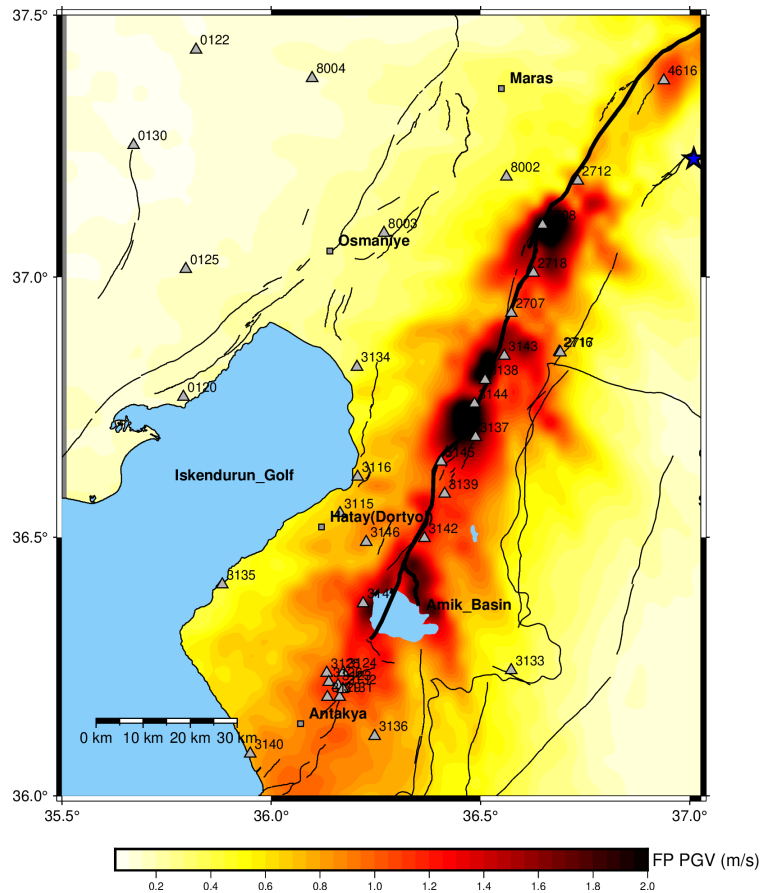
Use simulations to map PGV and PGA spatial variability



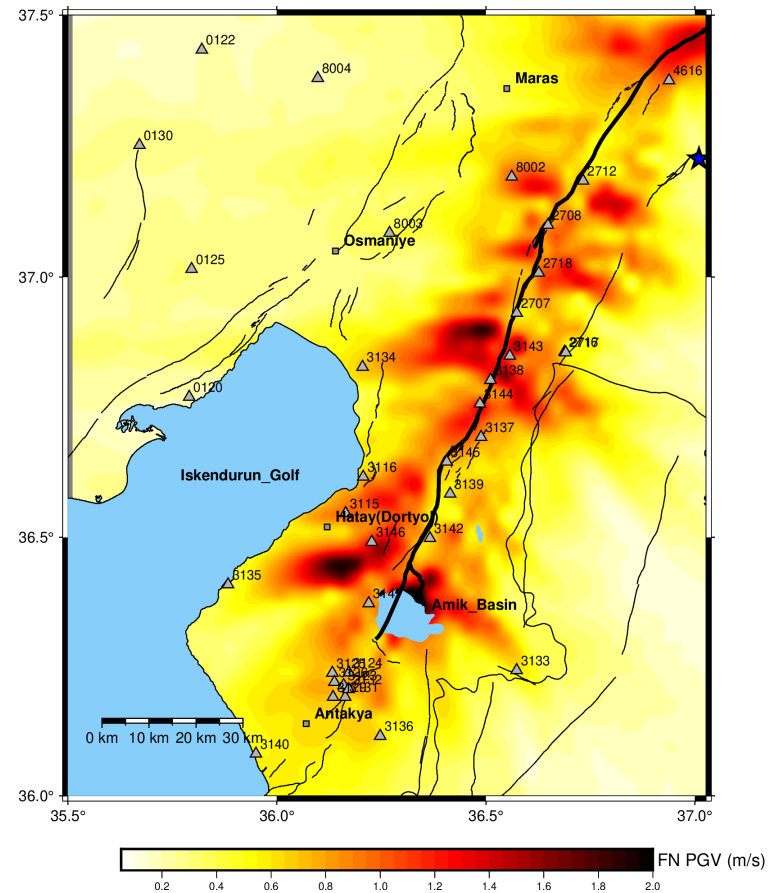
Near-fault FN and FP PGV maps



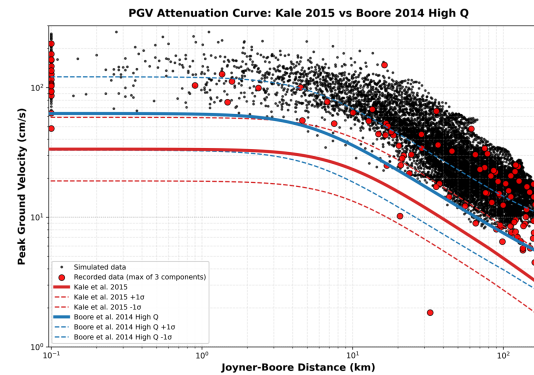
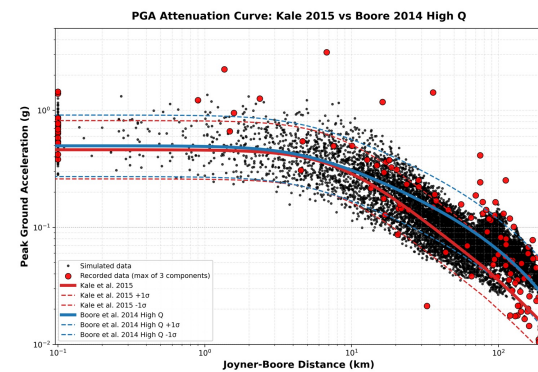
FN- PGV



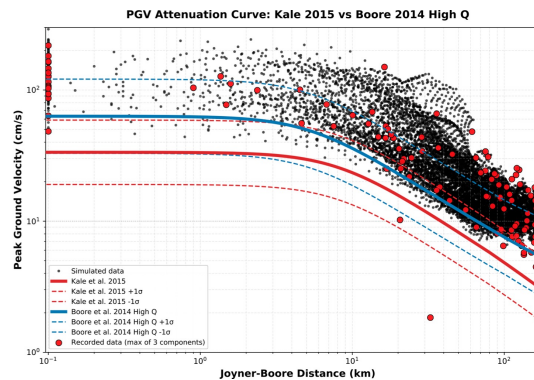
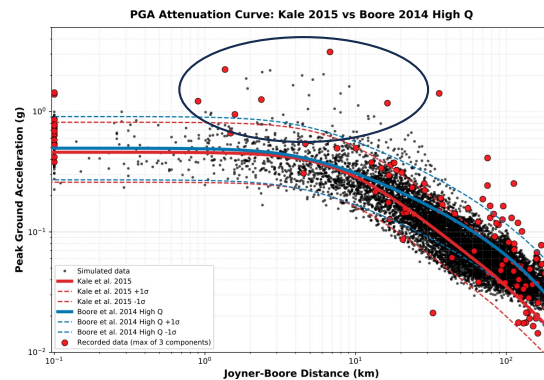
FP- PGV



Simulations match the recorded PGA and PGV GMMs underpredict the recorded PGA and PGV



This study



Simulation with a rupture realization
with modified slip patches
(Akinci et al., SSA 2026)

2. Use rupture realizations of the Turkiye earthquake to investigate sensitivity of near-fault ground motion amplitude and amplification pattern to rupture speed ($V_r = 0.72V_s - 1.5V_s$)

Rupture Realization	Rupture Velocity V_r
1	$V_r = 0.72V_s$
2	$V_r = 0.80V_s$
3	$V_r = 0.90V_s$
4	$V_r = 1.00V_s$
5	$V_r = 1.10V_s$
3	$V_r = 1.20V_s$
4	$V_r = 1.30V_s$
5	$V_r = 1.40V_s$
6	$V_r = 1.50V_s$

- The current GP rupture model is constrained using dynamic rupture modeling with undershear and near-shear rupture velocity
- This study assumes that the rupture physics is the same under-shear and supershear ruptures.

Research questions:

1. How well do we know the physics of the supershear rupture ?
2. What is the probability that a substantial part of the rupture goes supershear during a large crustal earthquake ?
3. Are our current kinematic rupture generators suitable for fully characterizing supershear rupture scenarios?

Rupture velocity effects on PGV

Undershear

Supershear

$$V_r = 0.70 V_s$$

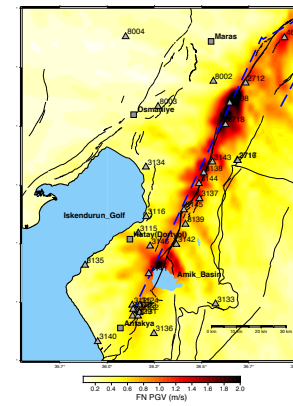
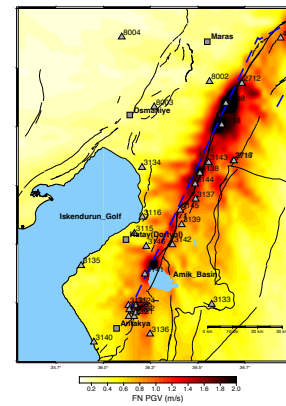
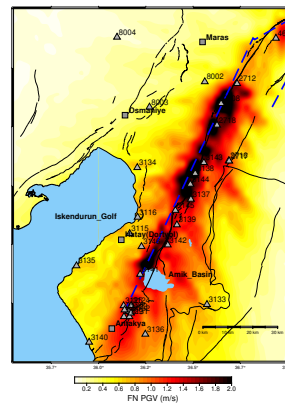
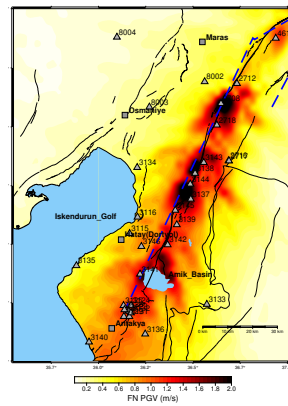
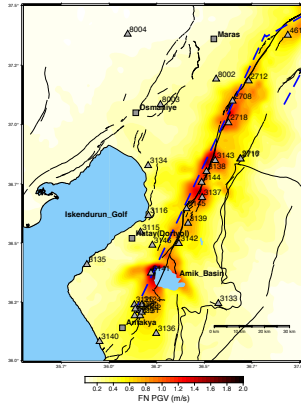
$$V_r = 0.90 V_s$$

$$V_r = 1.00 V_s$$

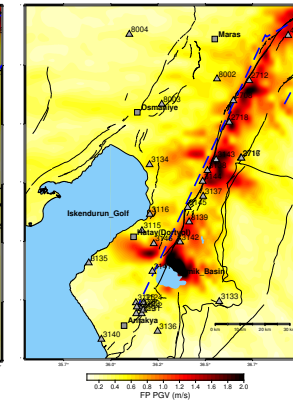
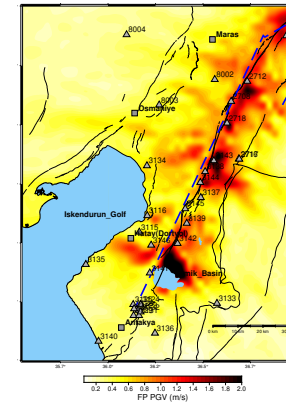
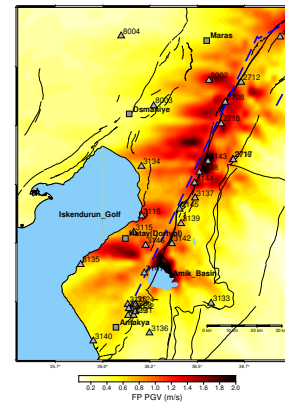
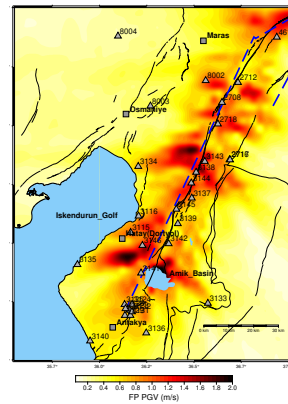
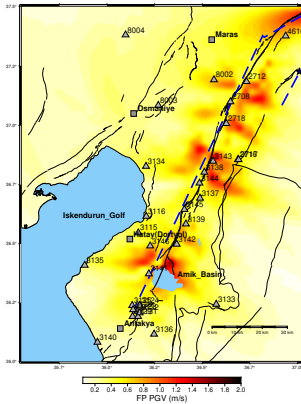
$$V_r = 1.10 V_s$$

$$V_r = 1.30 V_s$$

Comp:FN



Comp:FP

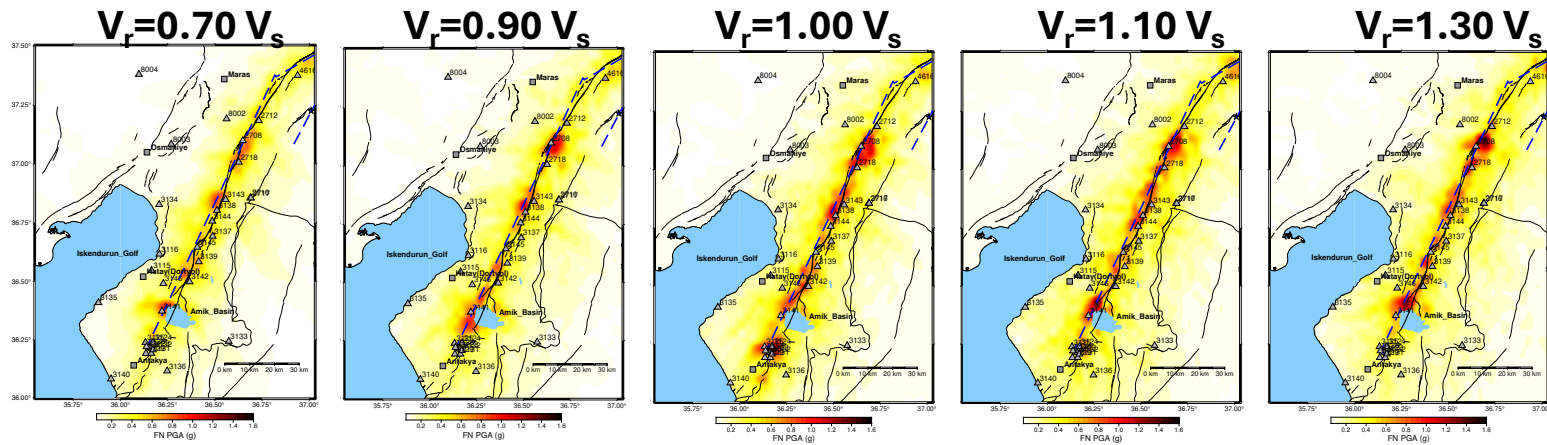


Rupture velocity effects on PGA

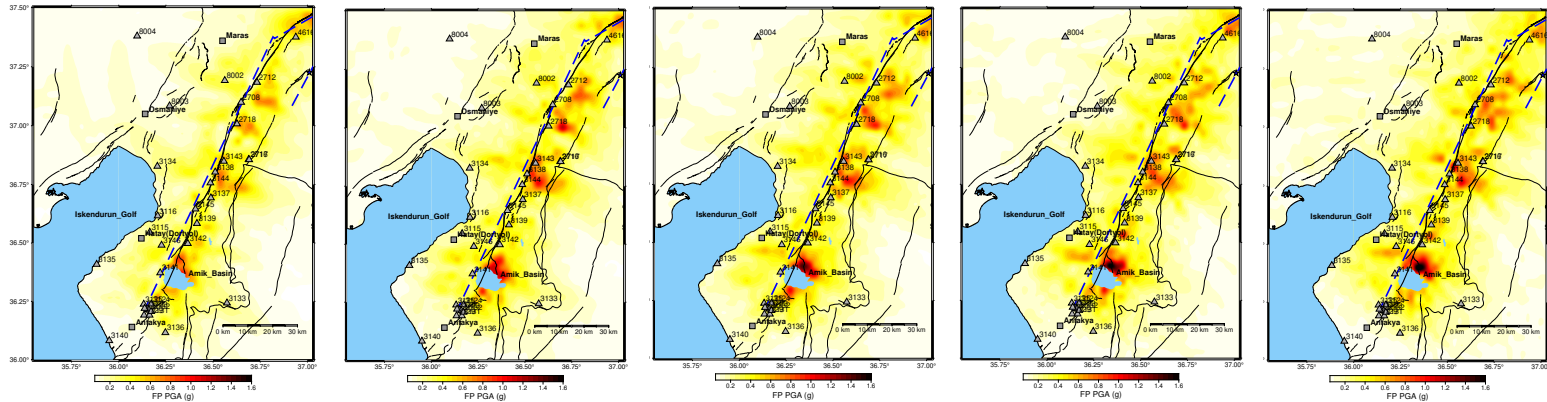
Undershear

Supershear

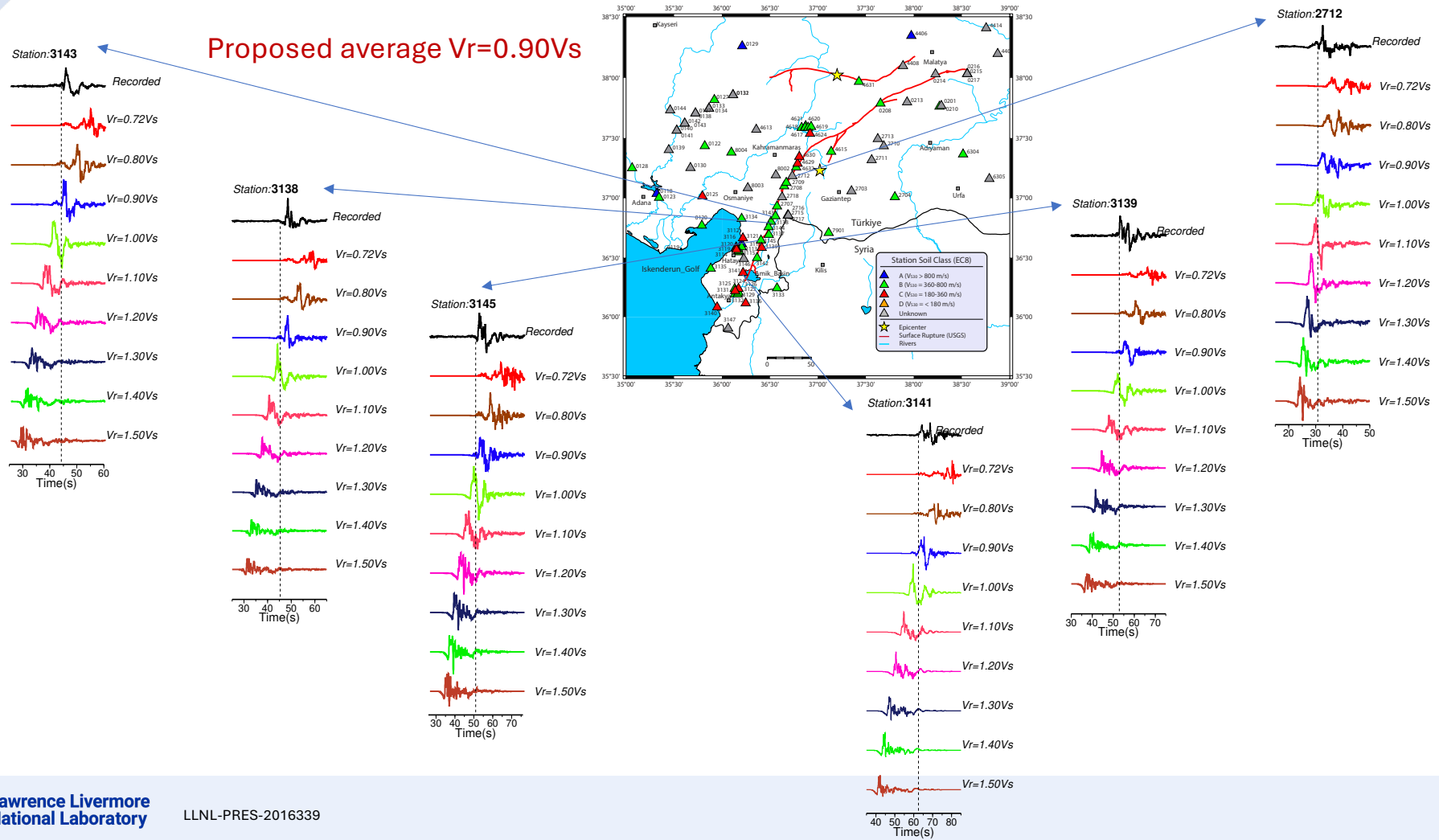
Comp:FN



Comp:FP



Effects of rupture velocity on near-fault ground motion FN component



Conclusions

1. The EQSIM platform performed well in reproducing the near-fault ground motion recorded during the 2023 Mw7.8 Türkiye earthquake. A hybrid slip model with large-slip patches, and an average rupture velocity of $V_r=0.9V_s$, produced a better fit to the recorded ground motion.
2. The rupture velocity might have been supershear in some parts of the fault, in areas with large-slip patches. FN amplification at near-fault sites caused by rupture directivity effects peaks for $V_r=1.0V_s$.
3. Simulations with different average rupture velocities in the range $0.72V_s$ - $1.5V_s$ show that the amplification pattern due to forward rupture directivity effects depends on rupture velocity. $V_r=1.0 V_s$ creates the strongest rupture directivity effect on FN ground motion amplification.
4. The simulations confirmed that the supershear rupture leads to large amplitude ground motions on both FN and FP components. The width of the amplification area is largest for near-shear ruptures, and decreases for both low and supershear rupture velocities.

Acknowledgements

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1. DOE EQSIM project
2. Nuclear Regulatory Authority of Japan, through a collaborative research project with the Ohsaki Research Institute, Tokyo, Japan
3. National Institute of Geophysics and Vulcanology (INGV) SECURE project, Italy

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